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Sensory and Control System for Smart Fan

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ABSTRACT
A smart fan is a development of an ordinary fan that consists of several features to help more comfortable and easier life. Ordinary stand fan is operated manually which people has to determine the speed of the fan and the oscillation of the fan is fix at a certain degrees. The smart fan is developed to have a speed regarding to the environment temperature and it will only operate as there is presence of human. Furthermore the fan is designed to oscillate with respect to the human location. To this extend, researches on the temperature controller and human location detection have been done and the system design explained in this report. The working principle of smart fan is interrelated between electromechanical, electronics and control system. The LM35 is used to determine the environment temperature meanwhile the passive infrared is used to determine the presence of human and ultrasonic sensors are used to detect the human location. The system is controlled by microcontroller which making the typical stand fan to be smarter.

Keywords- Smart fan, control system, sensor, movement detector, multiple objects detector.

1. INTRODUCTION
In the public area, people hesitate to turn off the fan after the usage. This lead to the wasting of energy. To avoid this situation, a fan that will be operated only in the presence of human is needed. The fan speed not according to the needs makes people feel uncomfortable. Furthermore, the fans that we have today oscillates to a certain angle irrespective of whether there are people or not. Thus, a fan that will operate in human presence and oscillate with respect to the human location is invented so that the usage of the fan can be optimized.

Fan is a mechanical device used to create flow within a fluid, typically a gas such as air. A fan usually consisting of various mechanical parts, including an impeller, a motor, a gearbox, and a lever gear usually being enclosed in a housing or casing. The rotation of the impeller driven by the motor creates air movement. Hence, fan is often used in cooling purposes as it increases heat transfer into the surrounding air due to the airflow from the fan. Typically a fan, such as a table fan or a standing fan, is set on a rotation axis in which air flow can be directed to areas at a fixed angle (usually 90^{o}) while the fan is oscillating. The on and/or off operation of the conventional fan is done manually so as the fan speed and the on/off operation for the oscillation of the fan. It is not uncommon that a person forgets to turn off the fan after his usage. This could be lead to wastage of energy. Though the setting of the fan is usually controllable with a remote control, it is still troublesome to change the fan speed too often if the room temperature is unstable. Further, airflow sometimes may be directed to area where there is absence of human when the fan is oscillating at a fixed angle. The fan usage is inefficient and not in the optimum condition. In view of the aforementioned problems, there is a need to develop an improved control system for fan which operates according to the presence of human, the position of human, and the ambient temperature, thereby reducing energy wastage, and improving efficiency and human comfort.

To overcome the problems a fan control system has been developed. Which allows the fan to operate according to the followings:

i. Presence of human
ii. The ambient temperature
iii. The position of humans

Thereby reducing energy wastage. The control system comprising a temperature sensing module for determining the surrounding temperature when the fan is operating; an object locating module for constantly detecting the location of an object or a human within an angle of oscillation of the fan; a motion detecting module for detecting the presence of human to trigger the operation of the temperature sensing module and the object locating module when there is presence of human; and a microcontroller for processing signals from the modules and provide output accordingly for on/off operation of the fan, varying the fan speed, and oscillation angle of the fan. In the preferred embodiment of the invention, the fan control system can be incorporated into any fan which oscillates at a fixed angle, such as a table fan and a standing fan. The motion detecting module detects the presence of human by continuously capturing a thermal image, in

which human silhouettes can be extracted from the background regardless of lighting conditions and colours of the human clothing, skin, and background.

2. RELATED WORKS

Smart fan or control system of similar products have been proposed and implemented for variety of applications. Sensors and circuits are used to develop the smart system. Temperature sensor, human detection sensor, and microcontroller are generally used. A brief survey of related works is presented in this section.

Basil Hamed stated that the 'smart house' technology is one realization of home automation ideals using a specific set of technologies. It's a house that highly advanced automatic system for lighting, temperature control, security, appliances and many other functions. In order to control the temperature LM35 temperature sensor is used where it is connected directly with DAQ [1]. Some researchers used Resistance Temperature Detector (RTD) for the temperature controller for industrial or home automation [2]-[5].

A costly sensor (Doppler radar occupancy sensor) using heart and respiratory signals is developed in order to improve stationary subject detection. Different levels of activity can be detected by this post-processing sensor's signal [6]. Although low cost passive infrared (PIR) sensor and ultra-sonic sensor are commonly used as occupancy sensors. The limitation of these sensors is generating false signal. But it can be overcome by using microcontroller [7]-[8].

The most crucial part of the system is human location detection. Location Detection Systems Location detection systems have been proposed and implemented in the literature for a variety of applications. The satellite based Global Positioning System (GPS) is commonly used in outdoor applications, [9]. In indoor, dense, or harsh environments GPS signals are affected by occlusions, reflections, and multipath effects. Radio (RF), infrared (IR), ultrasound (US), systems work well for their designed purposes. Radio : Radio waves provide a powerful means of location detection because of their ability to penetrate many types of surfaces and objects, and due to their range, scalability, and maintenance benefits. Rather than using differences in arrival time, as done by ultrasound systems, RF-based location detection systems determine location based on received signal strength, predicated on a known signal-to-noise ratio (SNR). RADAR [10] precomputes an SNR map for a building. A vector of signal strengths received at various base-stations iscompared with this map to determine position. Other RF-based systems include SpotON [11] and Nibble [12]. As with the previously mentioned schemes, there are still inherent issues of robustness when utilizing RF. The failure of a sensor or the introduction of new signal path from spurious re-flectors (e.g., people walking around) or shifting internal structures can severely impair existing systems. SNR-based systems have also the problem of being sensitive to environmental conditions. Recently, [13] suggested a scheme for location detection, based on computing the centroid of the positions of several base stations, that addresses some of these issues. However, this scheme applies to large open environments.

The Active Badge location system [14] was one of the first indoor location detection systems and is representative of the IR-based approach to indoor location detection [15], [16]. This system provides each person with a badge that periodically emits a unique ID using diffused IR that is received by one of several receivers scattered throughout a building. Badge location is then resolved by proximity to the nearest receiver. In harsh settings, however, the communication environment can be very dynamic, as people move about, smoke or other impurities fill the air, or walls collapse. In such settings, proximity to a single receiver is not sufficiently robust or flexible to provide reliable location detection.

Ultra-sonic (US) based systems also provide location detection based on proximity, but improve accuracy by measuring ultrasound time-of-flight with respect to a reference RF signal. Systems such as the Active Bat [17] or MIT's Cricket [18] compare the arrival time of the two signals from various known sensors in order to calculate a listener's location. As with the IR-based schemes, current US-based systems are not designed for robustness, since line-of-sight paths may get obstructed or altered in the face of changing room dynamics. In addition, these systems are particularly sensitive to the possible destruction of sensors.

A large number of product and system have been developed using one or more of the sensors described above. Some of the products similar to the proposed smart fan are patented. Li hui and Zhou Chunmei patented "Intelligent electric fan" (CN203532298). "Automatic occupancy and temperature control for ceiling fan operation" (US5996898(A)) patented by Parker et.al. in 1999. Takashi et.al. patented (WO2010074328-30 (A1)) "Air conditioner indoor unit with human body detection device and obstacle detection device" in 2010. However, system for automatic oscillating according to the human position has not been included any of the inventions.

3. PROTOTYPE DEVELOPMENT

The design of the fan is the same as the conventional stand fan. The change made is only in the controller of the fan. The conventional stand fan does not have motion detection and temperature detection. Thus, these two subsystems are added to achieve the objectives of this project.

The function of motion detection part is to turn on the whole system. The fan will not rotating until there is presence of human. The idea of having motion detection to be embedded in this system is come from the burglar alarm system. The system is using the passive infrared sensor to detect the motion of intruder. The details on how the passive infrared works will be discussed in the sub topic entitled component selection.

Meanwhile, the function of the temperature detection is to detect the ambient temperature so that the speed of the fan can be regulated depending on the suitable temperature. The relays are used as switch to turn on three different speeds which are slow, medium and fast.

The location detection used in this system is the new development in which combination of servo motor and ultrasonic sensor is used. The servo motor will rotate periodically in a fix degree and an ultrasonic sensor is attached to it. That ultrasonic will detect the smallest distance of person that appear in front of the fan. The smallest distance of human will be the input to the limitation of degree of oscillation.

3.1 Design of Location Detection System

The servo motor will start its oscillation from 10^o until 170^o. That means the span of the oscillation is 160^o. Initially, the servo will start at 10^o and then rotate anti clockwise up to 170^o. The servo is then turning back to its initial position with the same speed. This servo will keep oscillate as long as the passive infrared sensor detecting motion. Figure 1 shows the drawing of the area of the location will be detected.

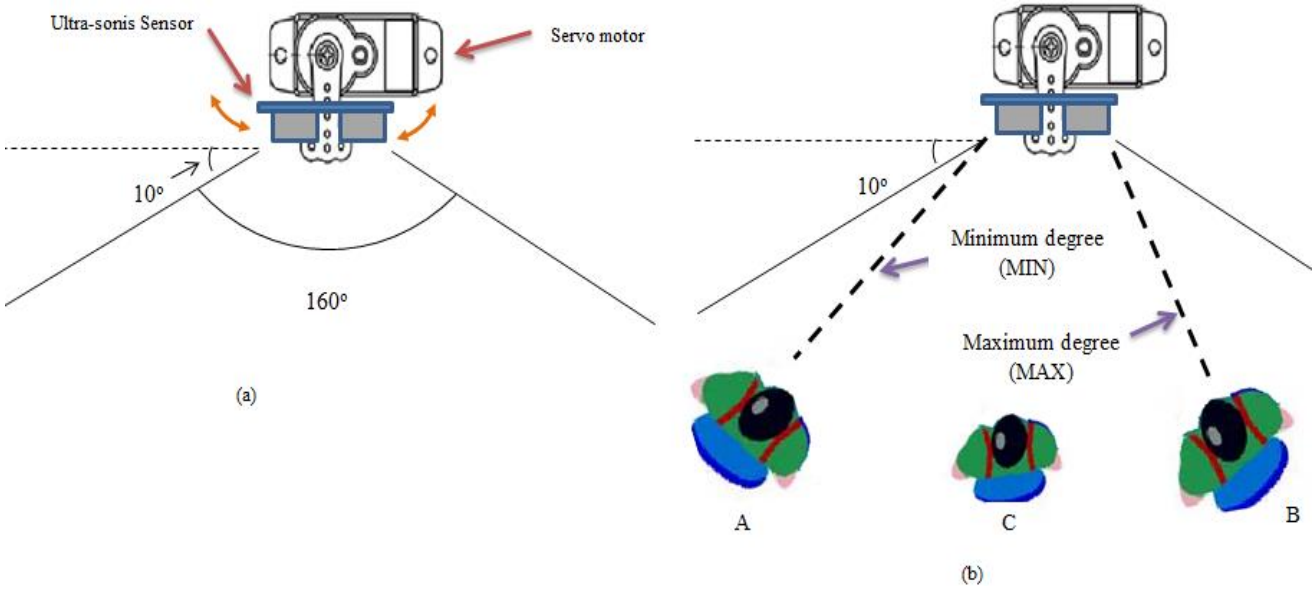

Figure 1 Location detection System

As the servo rotate anti clockwise, the servo will first detected human at location A. The degree of A is taken as the initial limit. However, the servo will finish it rotation until 170^o. As it keep rotating, there is another human detected at location B. The system will take the latest value which means the degree of B is now replacing the value of A. The value of B is set as the maximum degree that the fan will oscillate. As the servo completed 170^o, it will turn back to its initial position. Same process happened but at this time, the degree of A is the latest value. The value of A is set as the minimum degree that the fan will oscillate.

Let put another person in between person A and person B. The degree of location C will not be taken as limitation value because the latest value for clockwise rotation is at A and the latest value of anti-clockwise rotation is B. This is fulfill the requirement as the fan oscillate in the limit of A-B, the person at location C will still in the range of fan oscillation.

3.2 Motion and Temperature Detection

The passive infrared sensor is act as the main switch of the system. The signal pin is connected to analog port to give analog signal to the controller. If there is value given from the passive infrared, the controller will start to give instruction to temperature sensor. Otherwise, the sensor will assume that there is no user

The temperature sensor will only operate as the PIR sensor energized. The LM35 will then detecting the ambient temperature and the controller will regulate the speed of the fan regarding to the detected ambient temperature.

3.3 Circuit

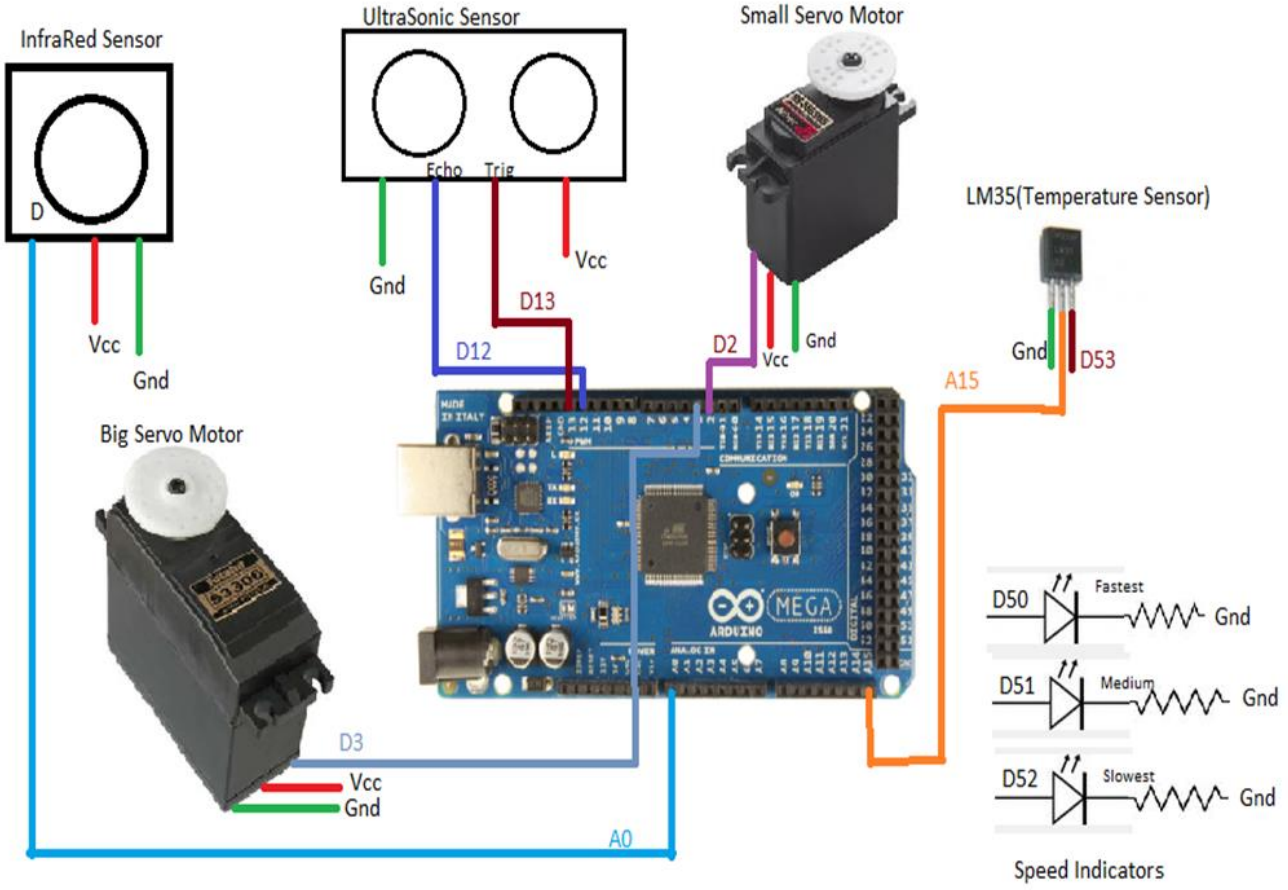

Figure 2 Circuit diagram of the system

Figure 2 shows the connections of sensors and actuators used to the microcontroller, Arduino Mega. The signal port of the passive infrared sensor is connected to the analog port (A0) of the arduino which already defined as input port in the program code. This input then will triger the digital port (D53) which is the voltage pin of the temperature sensor, LM35. As the LM35 obtained the source, the embient temperature can be measured. The signal pin of LM35 is then connected to analog port (A15), defined as input pin. This input will determine the speed of the fan which the output connected to port D50,D51 and D52.

Finish with the circuit connection to turn on/off the fan and determining the speed of the fan. Now, the circuit connection to determine the location of human will be explained. Ultarsonic sensor consist of echo pin and triger pin. Both pins act as transmitter and receiver. Echo pin is connected to PWM port (D12) and triger pin also connected to PWM port (D13). The ultrasonic sensor works simultaneously with the small servo motor. The signal pin of the small servo motor is connected to PWM port (D2). The data obtained from D2 is then being the input to the giant servo motor which connected to D3.

4. RESULT AND DISCUSSION

4.1 Operating principle

The operating principle of the smart fan is shown in figure 3. An object locating module for constantly detecting the location of an object or a human within an angle of oscillation of the fan; a motion detecting module for detecting the presence of human to trigger the operation of the temperature sensing module and the object locating module when there is presence of human; and a microcontroller for processing signals from the modules and provide output accordingly for on/off operation of the fan, varying the fan speed, and oscillation angle of the fan.

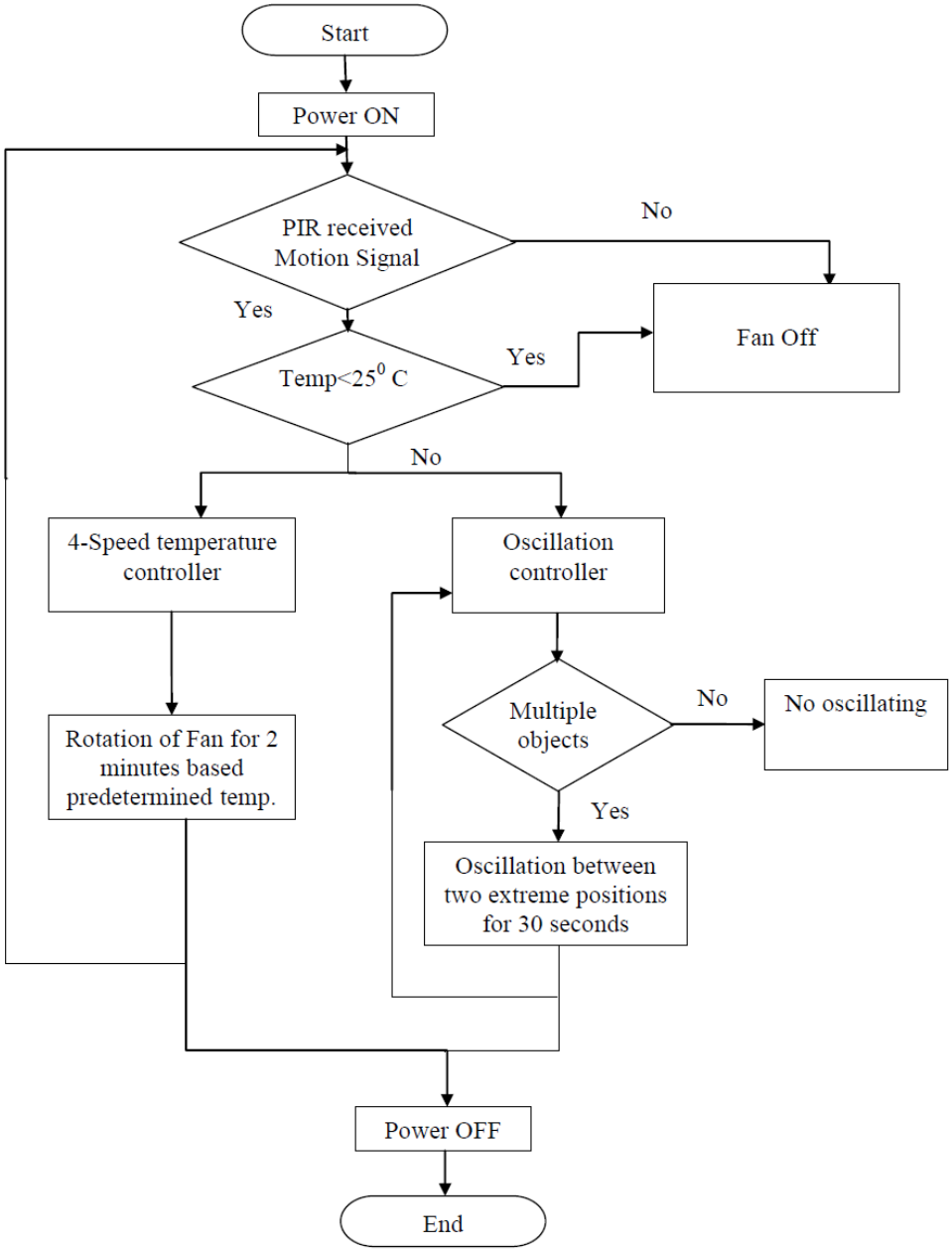

Figure 3 Flow chart of the fan control system

4.2 Human Location Detection

The human location detection part is the most crucial part and this part was tested many times to get the desired output. As the servo motor starts to operate, the ultrasonic will also start to measure the object/human distance. The servo motor will start from 10^o and keep moving until 170^o with 1^o of increment. At the same time, the temperature sensor is measuring the ambient temperature. After the MAX value obtained, the giant servo motor which located at the neck of the fan will turn to the MAX value. From the data obtained, we can see that the data next to the MAX value shows that the system start to find the MIN value and starts with 170^o. The degree will be decremented by 1^o until it reaches 10^o. Graph in Figure 4 shows that there are three object/human detected in the range of below 20cm. However, the system will only take the highest value of angle among these three locations to be used as MAX value.

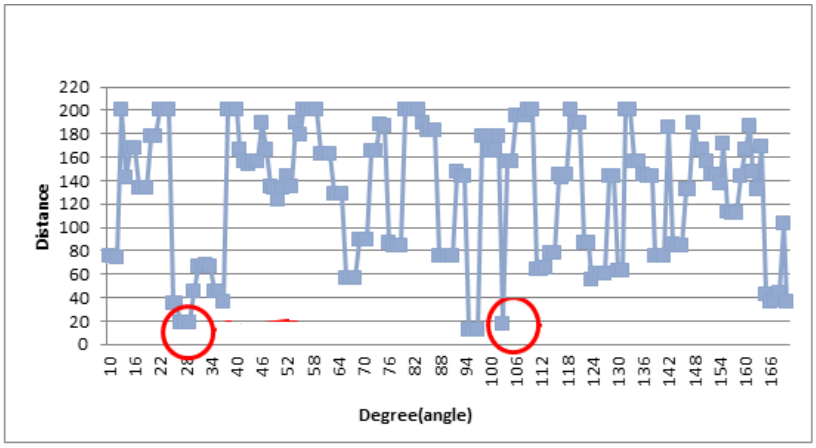

Figure 4 Graphical presentation of data from location detecting system

The process of determining the MIN value is same as determining the MAX value. The graph below shows the same data used to detect the object/human location. However, for this part the system will take the lowest value of angle to be used as MIN value. From the graph, the MIN value will be 27 degree. This data is then will be used by giant servo motor as the MIN limitation of the oscillation. Now, the fan will oscillate from 27^o until 111^o instead of 10^o to 170^o.

Finally the operating conditions is monitored. Figure 5. shows the data obtained from the serial monitor connected to the microcontroller.

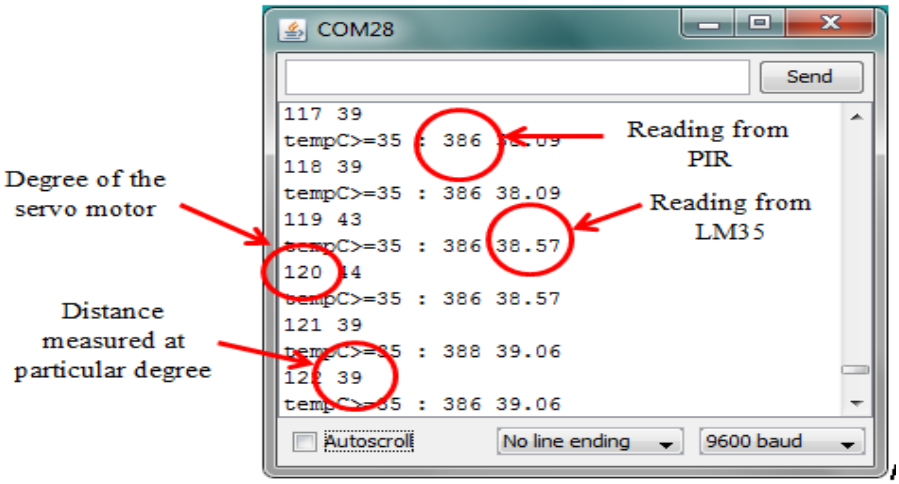

Figure 5 Operating state data

5. Discussion

Based on the result obtained from the PIR sensor, the response is very fast in which the fan will turn on as there is motion detected. However, the limitation of the system is found where the fan will turn off if the person that the PIR detected earlier is not moving. The fan will turn on again if there is motion made by the user even with small movement for example waving the hand. This limitation makes the fan lack of reliability where the users have to make a movement to make the fan to keep turn on. However, there is one way found to solve this problem in which the fan will be keep operating in 2 minutes even though there is no motion detected. This can be done by putting delay 2 minutes in the coding.

In term of the location detection, the distance measured by the ultrasonic is accurate. Moreover, the ultrasonic used is able to measured distance up to 400cm. However, the problem is the result will not accurate if the motion of the servo motor is fast. This is because the signal produce by trigger will take time to it reflected to the echo. If the servo motor moves fast, the echo will obtained different signal. To avoid this thing to happen, the speed of servo motor is reduced in which the servo moves 10^o per second. Meanwhile, the range of the oscillation is 160^o. This means that the time taken to the servo to find the MAX value is 16s. To make the servo to finish it full cycle is 32s.

For the oscillation part, the giant servo motor need to wait 16s to it go turn to the maximum limitation. After it goes to the maximum limitation, it will stop there and wait another 16s to go to the minimum limitation as the program code is

executed line by line. To avoid this thing to happen, an idea has come across which the combination of two arduinos is needed. The first arduino act as master controller. It will control the whole system. Meanwhile, the second arduino will act as the slave. It will only controlling the oscillation part. The data from the master controller will be transmitted to the slave controller. This will make the servo motor for the location detection and the servo motor for the oscillation can work simultaneously without have to wait the other to finish it task.

6. CONCLUSIONS

A control system for a fan comprising a temperature sensing module for determining the surrounding temperature when the fan is operating. An object locating module for constantly detecting the location of objects or human within an angle of oscillation of the fan; a motion detecting module for detecting the presence of humans to trigger the operation of the temperature sensing module and the object locating module when there is presence of human; and a microcontroller for processing signals from the modules and provide output accordingly for on/off operation of the fan, varying the fan speed, and oscillation angle of the fan.

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